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CIRCULARITY OF CONSTRUCTION MATERIALS IN ARCHITECTURAL HERITAGE PRESERVATION

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Rezumat. *Clădirile istorice reprezintă ansanmblul aspectelor legate de arhitectură, materiale și tehnologia epocii în care au fost construite și contribuie la cunoașterea* celor *contemporane. Materialele rezultate din demolarea clădirilor vechi, precum: cărămizi, materiale lemnoase și vegetale, beton, pietriș, piatră și nisip, zidărie și moloz, metale, plastic, sticlă, gips-carton, carton și hârtie, corpuri sanitare, fibre (azbest, sticla, otel, naturale), pot căpăta o nouă viață, devenind parte a unei noi clădiri, străzi, fațade sau chiar a unui oraș, in contextul arhitecturii circulare si a conceptului Smart City. Cazul specimenelor pe baza de deseuri poliuretanice vor fi discutate in aceasta lucrare, ca înlocuitori parțiali in compoziția unor noi structuri de construcție. De asemenea, metode de caracterizare și testare a acestor noi compoziții vor fi discutate și evaluate.*

Abstract. *Historic buildings represent an ensemble of related to architecture, materials and technology of the era in which they were built and contribute to the knowledge of contemporary ones. Materials resulting from the demolition of old buildings, such as: bricks, wood and vegetal materials, concrete, gravel, stone and sand, masonry and rubble, metals, plastic, glass, drywall, cardboard and paper, sanitary fixtures, fibers (asbestos, glass, steel, natural), can get a new life, becoming part of a new building, streets, facades or even a city, in the context of circular architecture and the Smart City concept. The case of the specimens based on polyurethane waste will be discussed in this paper, as partial substitutes in the composition of new building structures. Also, methods for characterization and testing of these new compositions will be discussed and evaluated.*

Keywords: Circularity; circular economy; materials; cultural heritage; architecture.

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1. Introduction

The concept of circular architecture, which involves the reuse of building materials from demolitions for new construction projects, is not only a sustainable approach, but also a way of preserving the architectural, technological and functional elements of historic buildings. By reusing materials from old structures, it is possible to incorporate valuable historic features into modern designs while reducing waste and environmental impact [1].

The circular economy (EC) is currently promoted through political, urban and regional strategies, and the general principles of EC are applied to existing and new buildings, focusing on the development of innovative sustainable solutions to optimize the dismantling and reuse of materials and technological parts of buildings [2].

The adaptive reuse of cultural heritage seems to be one of the most viable solutions to apply CE in the historical built environment. In this article, we aim to identify CE solutions and for the future development of a system of indicators capable of supporting circular adaptive reuse options in the historic built environment.

Recycling and reusing demolition concrete waste play a significant role in mitigating the environmental impact of construction activities. By utilizing recycled aggregates from demolition waste, it not only reduces the burden on landfills but also helps conserve natural resources while decreasing energy consumption associated with sourcing virgin materials. Incorporating sustainable practices like recycling concrete waste can lead to a more efficient and environmentally friendly construction industry [3].

It is evident that various factors such as structural issues, obsolescence, and natural disasters may require the demolition of old structures, leading to the generation of debris that necessitates reconstruction. Investing in new construction projects is crucial for economic growth and ensuring that infrastructure aligns with current needs. Strategic demolition and reconstruction practices not only revitalize communities but also support sustainable development by incorporating modern technology, materials, and designs for efficient, resilient, and environmentally friendly structures. [4].

The comprehensive recycling procedures involved in manufacturing high-grade recycled concrete aggregates (RCA) comprise crushing, pre-sizing, sorting, sieving, and decontamination processes. By meticulously executing these stages, refined and top-quality aggregates are produced, aligning seamlessly with design requirements and ensuring an exceptional final product suitable for diverse construction applications. Further cleaning methodologies are employed to eradicate impurities such as dirt, clay, wood, plastic, and organics, utilizing techniques like water floating, manual sorting, air separators, and electromagnetic separators. This stringent methodology guarantees that the ultimate recycled concrete material adheres to rigorous quality benchmarks, free from undesired components, streamlining its utilization in construction endeavors [5].

The materials resulted from their demolition, such as: bricks, wood and plant materials, concrete, gravel, stone and sand, masonry and rubble, metals, plastic, glass, plasterboard, cardboard and paper, sanitary fittings, fibbers (asbestos, glass, steel, natural), are under progress in our group, and only polyurethane waste will be discussed in this paper, as partial substitutes in the composition of new construction structures.

The latest report from Plastic Europe demonstrates a rise in plastic demand in Europe, reaching 49.9 MTn in 2016, and approximately 70% exists in the form of foam, from which about 27% results in waste, leading to 31.1% recycling, 41.3% incineration, and 27.3% landfill disposal [6]. The major sectors driving demand are construction and building, automotive, refrigeration, and various others within industries like textiles and technology.

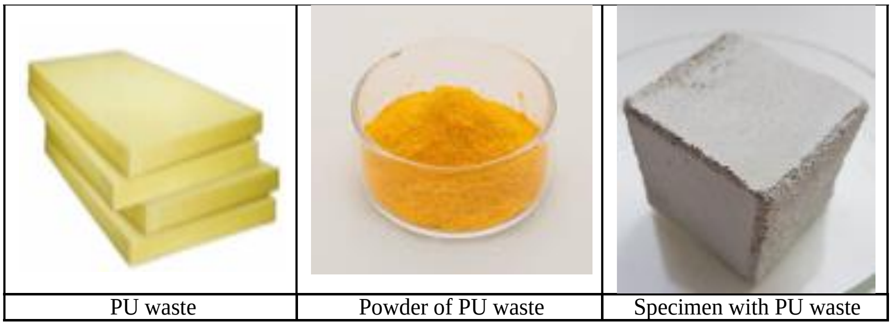
Also, methods of characterization and testing of these new compositions will be discussed and evaluated, too.

2. Experimental part

2.1.Materials

The experimentation with different waste materials such as polyurethane waste by creating 5 x 5 x 5 cm specimens (Fig.1) allowed for comprehensive evaluations through structural, compositional, and microscopic analyses, as well as assessments of their durability against external factors and mechanical stresses. This approach not only explores the potential use of waste materials in construction but also evaluates their performance under practical conditions, highlighting the importance of sustainable practices in the construction industry.

In this paper, some specimens with PU will be prepared and tested accordingly, as it is presented in Figure 1.



PU waste | Powder of PU waste | Specimen with PU waste

Fig. 1. PU waste, PU powder and specimen with PU waste

Polyurethane foam wastes, originating from insulation panels utilized in the building industry, were sourced from a manufacturer in two distinct categories: coarse waste, characterized by particles larger than 10 mm, and fine waste abundant in fine particles with a size equal to or less than 10 mm.

2.2. Preparation of specimens

The mortars were meticulously prepared with a precise 1:2 cement/aggregate ratio and a 1:1 water/cement ratio by weight to ensure optimal workability and flow properties, accounting for the incorporation of polyurethane as substitutions in different proportions (2, 4 and 10 g). These materials were used to partially replace Portland cement in the mix.

2.3. Tests

The capillarity test was performed according to the procedure adapted after [7] and is a simple experiment simulating the action of increasing humidity through capillarity. The capillarity test consists of measuring water absorption by capillarity and allows to evaluate the amount of water absorbed by capillary growth in a certain time and was performed on parallelepiped-shaped artificial stones with a size of 2×2×7 mm. The specimens have been placed in a Petri vessel and then add water at a height of 1 cm from the base of the sample. Measure height (H) every minute for 5 minutes, every 5 minutes for 25 minutes and then every 30 minutes.

The compressive strength test was performed with a Silver Schmidt Hammer Proceq test hammer, type L with impact energy 0,735 Nm, according to ASTM C805. The strength test range with the Silver Schmidt hammer is 10-100 N/mm^2. 10 measurements were made for each sample and recordings were made at a minimum test distance of 25 mm between every two test points and a minimum edge distance of 25 mm. The hammer has been positioned 90° downwards and the recoil number value (Q) is calculated as an average of the readings with the aim of finding a relationship between surface hardness and compressive strength with an acceptable error. Rebound number measurements were used and then compressive strength determined according to ASTM C805.

3. Results and discussion

The water absorption coefficient was measured following the guidelines outlined in European standard EN 1015-18, using specimens of dimensions 40 mm x 40 mm x 160 mm to assess the capillary action of hardened mortar [7-9].

Specimen samples are drying to constant mass, and then one face of the specimens is immersed in water at a depth of 500 mm for a specific period of time (normally 10 and 90 min.). The measurements were done at the following intervals: 5, 10, 20, 30, 40, 50, 60, 70, 80, 90 min and 150 min, to show the development of this parameter in time. The increase in mass is determined. Capillarity is characterized by water absorption coefficient A_w according to Equation (1):

$$A_w = (m_i - m_t) / A * t^{1/2} \, (kg / m^2 * h^{0.5}) \qquad (1)$$

where:
m_i = initial mass of the specimen
m_t = specimen mass at different time;
A = water contact surface.
T = time of water immersion.

Water absorption coefficient expresses the rate of capillarity action in certain time. Aw is mathematically defined as a tangent to capillary water content function.
Likewise, the height of the water, drawn upwards by capillarity action, was determined as shown in Figure 2. According to this European standard, the Capillary Absorption Coefficient value of the mortar, was calculated as 0.175 $Kg/(m^2 \cdot min^{0.5})$, corresponds to classification W_2 ($c \leq 0.2$ $Kg/(m^2 \cdot min^{0.5})$), with the water rising to an average height of 10.0 mm [8-10].

The mechanical strength of polyurethane mortar samples is shown in Figure 3, indicating a mechanical strength close to that of a normal cement, in good agreement with literature [11-15].

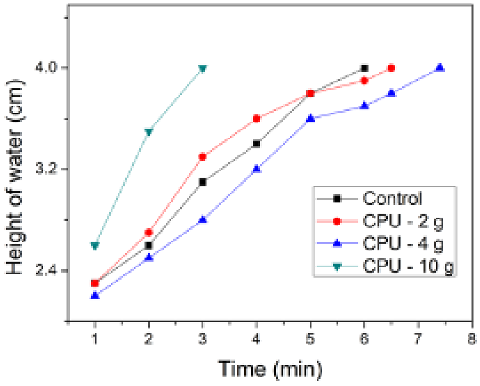


Fig.2. Variation of height of water in specimens with polyurethane RCA

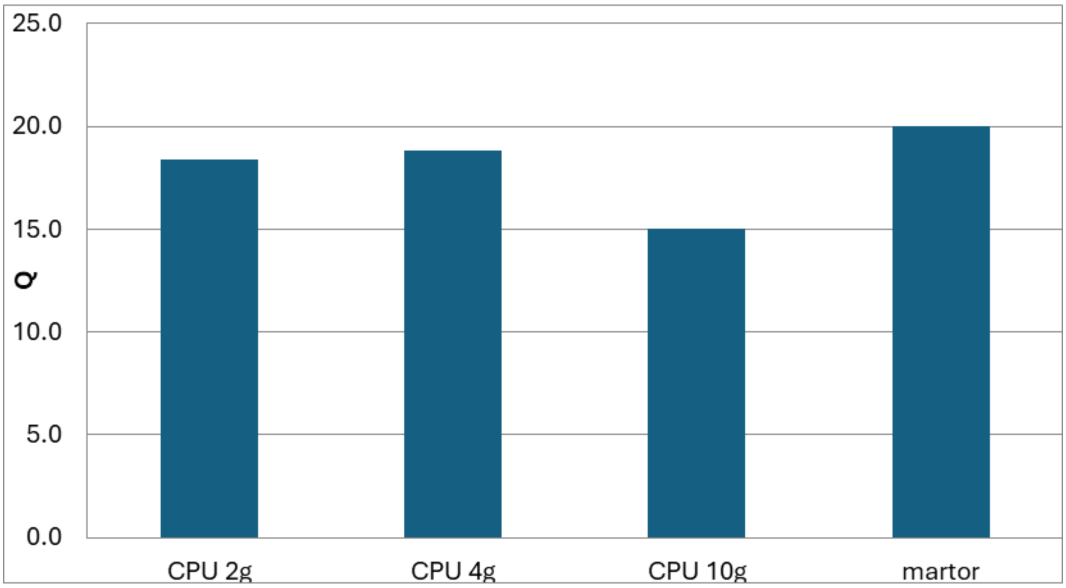


Fig.3. Variation of mechanical resistance in specimens with polyurethane RCA

A higher mechanical strength (7 MPa) than the initial mechanical strength (5 MPa) is registered after 24 hours. At 28 days, these values became 10 MPa, and after 50 days they became 18 MPa.

4. Conclusions

The waste resulted from demolished buildings consist in various materials like bricks, wood, concrete, metals, and others. Instead of disposing of these materials, there is an emerging trend towards incorporating them into new construction projects, promoting circular architecture and supporting the Smart City concept. In the context of reusing materials, this paper presented the use of polyurethane waste specimens as partial substitutes in new building structures. The study presented few examples of concrete with polyurethane waste specimens as novel compositions to assess their viability and effectiveness in sustainable construction practices.

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R E F E R E N C E S

[1] I. Papamichael, I., *et al.*, Waste Management & Research, **41**, 1728 (2023).

[2] M. Bergonzoni, *et al.*, Procedia Computer Science, **217**, 41 (2023)

[3] C.K. Purchase, *et al*., Material*s*, **15**, 76 (2022)

[4] G.L.F. Benachio, et al., Journal of Cleaner Production, vol.260, no. 121046 (2020).

[5] European Commission, New Circular Economy Action Plan New for a Cleaner and More Competitive Europe. Brussels, pp. 1–27 (2021).

[6] Construction and demolition waste: Challenges and opportunities in a circular economy (2020) https://www.eea.europa.eu/publications/construction-and-demolition-waste-challenges

[7] J.M. Teutonico, *A laboratory manual for architectural conservators*. **16** (1988): ICCROM Rome.

[8] K. Hamad, *et al.*, Polymer Degradation and Stability, **98**, 12, 2801 (2013).

[9] A. Sicakovaa, *et. al.*, Procedia Engineering, **180**, 1256 (2017)

[10] R. Gómez-Rojo *et al.*, Polymers, **11**, (2019).

[11] C. Junco, Construction and Buildings Materials, **190**, 373 (2018).

[12] P. Mounanga, *et al.,* Cement and Concrete Composites, **30,** 806 (2008)

[13] M. Kismi, and P. Mounanga, Proc. on 2nd International Seminar on Innovation and Valorization in Civil Engineering and Construction Materials, 2, 02019 (2012)

[14] J. Gadea, *et al.*, Composites, **32,** 672 (2010).

[15] V.Fruth; *et al.*, Nanomaterials **11**, 2586 (2021)